Stereo Matching Technique using Belief Propagation

Annual Progress Seminar-I

By

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What is Stereo Matching

- Stereo Matching is for given two or more images of the same scene or object, compute a representation of its shape.
- Stereo Matching is process of finding disparity or depth information.
- The key problem to solve stereo vision are to identify which pixel in multiple images match the same feature .This problem is known as stereo matching or stereo correspondence.
- Stereo matching is necessary key functionality has many applications.

Applications of Stereo Matching

- Image sequence analysis in entertainment, information transfer and automated systems.
- Stereo matching is highly important in fields such as robotics to extract information about the relative position of 3D objects and for object recognition where depth information is used to separate occluding image components
- Scientific applications such as extracts information from aerial surveys and for calculation of contour maps or calculation of 3D heliographic information such as obtained by the remote sensing projects of the ISRO .

Classification stereo algorithm

- The stereo algorithms are categorized as Area-Based Algorithms, Feature- Based Algorithms and Global Algorithms .
- Problem in Area- Based Algorithms is to find the optimal size of the window and disadvantage of the Feature-Based Algorithms is that they usually yield sparse disparity maps.
- The Global Algorithms performed over the whole images. Example : Graph Cut Method,Belief Propagation

Outline

1. Stereo Matching Technique
    1. Match cost computation
    2. Cost Aggregation
    3. Disparity Optimization
    4. Disparity refinement
2. Research Plan
3. Conclusion

Stereo algorithm

- **Step1:Match cost computation**
- The cost is for every disparity value ,the cost function is intensity differences between two pixels.
- In probability term ,the disparity value of each pixel is random variable it takes N discrete values.
- The cost function is defined as $\Phi(x_p, y_p)$

Stereo algorithm

- **Step2:Cost Aggregation**
- A MRF approaches uses second compatibility function which expresses compatibility between neighboring variables. This is known as pair wise random field .
- The compatibility function is $\Psi(x_i, x_j)$
- The joint probability of these two functions are:

$$P(x_1, x_2, .x_N, y_1, y_2, ..y_N) = \prod_{ij} \Psi(x_i, x_j) \prod_{p} \Phi(x_p, y_p) \qquad (1)$$

- Where N is number of nodes,(i ,j) pair of neighboring nodes

Stereo algorithm

- **Step3:Disparity Optimization**
- Maximum A Posteriori (MAP) estimator is used to optimize the disparity for stereo images.
- By maximizing the probability means taking log of above equation (1)
- To maximize probability means minimizing function in the form of

$$P(x_1, x_2, .x_N, y_1, y_2, ..y_N) = \sum_{i,j} -\log \Psi(x_i, x_j) + \sum_{p} -\log \Phi(x_p, y_p) \tag{2}$$

It can be expressed as

$$P(x_1, x_2, .x_N, y_1, y_2, ..y_N) = \sum_{i,j} V(x_i x_j) + \sum_{p} D(x_p, y_p)) \tag{3}$$

- These functions are energy functions.

Stereo algorithm

- **Step4:Disparity refinement**
- The loopy Belief propagation algorithm is used to find the solution for data and smoothness cost functions.
- The Belief Propagation algorithm classified as Sum-Product Algorithm or Max-Product Algorithm.
- The Sum-Product Algorithm finds the marginal distributions of node while Max-Product Algorithm finds MAP estimate of whole image.
- For stereo algorithm mostly Max-Product Algorithm is used. The Max-Product Algorithm find best label for whole MRF.
- loopy Belief propagation algorithm converts cost functions into exponential functions and finds approximate match

Advantage of Belief Propagation

- The stereo matching problems can formulate in terms of Markov Random Field as minimum energy function, to find energy minimization function is NP-hard.
- This means a general solution to this problem will take an unthinkably long time to reach a solution.
- Belief propagation algorithm is an approach which find the approximate solution for minimum energy functions used for stereo matching.
- Belief propagation algorithm considers both vertical and horizontal consistency, is most robust method in the presence of texture less and occlusion regions

Research Plan

1. **stage1**: MRF formulation on stereo image
2. **stage2**: Application of BP to find minimum energy functions

Research Plan(MRF Formulation)

- MRF are undirected graphical model consist of nodes and links which encodes the spatial dependencies.
- The blue nodes are observed variables which represents pixel intensity values where as pink nodes are hidden variables which represents disparity values are trying to find.
- The hidden values are referred as labels.The link between these node represents a dependency which is known as markov assumption.
- A markov assumption is that a node's state depends only on its immediate neighbors .This assumption is used to solve for the hidden variables in a efficient manner.

Research Plan (MRF Formulation)

MRF is modelled on 3×3 stereo image.

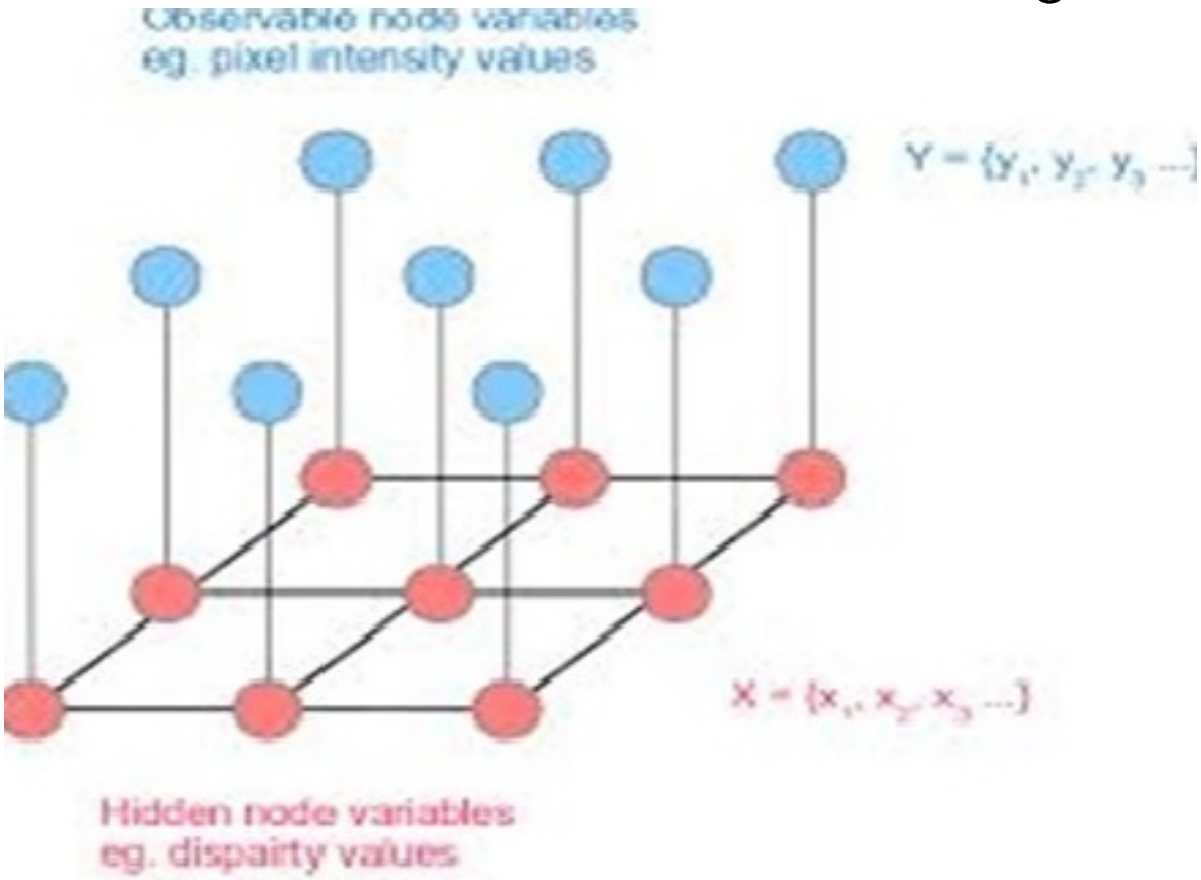


Figure: MRF on 3x3 Image

Research Plan (MRF Formulation)

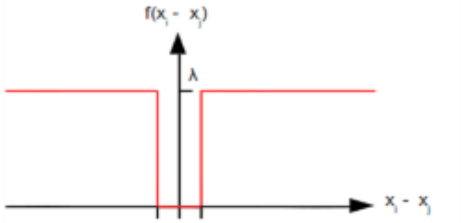
- The stereo problem can formulate in terms of MRF as energy functions. The energy functions basically sum up all the cost at each link for a given image and label.
- The aim is to find label that produces lowest energy. The energy function consists of two functions, datacost function and smoothnesscost function.
- The datacost function finds the cost ie.assigning label value to data.The function used for this is absolute difference function.

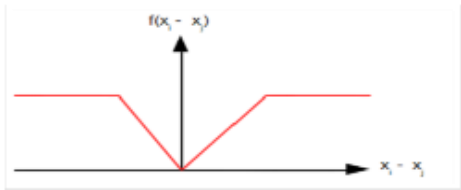
Research Plan (MRF Formulation)

- The SmoothnessCost function known as the pairwise energy or term or potential
- SmoothnessCost function enforces smooth labeling across adjacent hidden nodes ie a function that penalizes adjacent labels that are different
- Some commonly used cost functions are
  1. Binary function
  2. Linear function
  3. Quadratic function

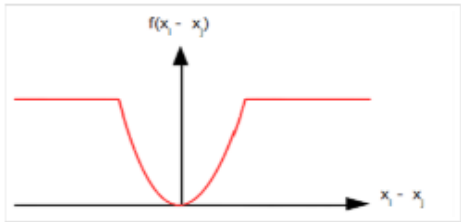
Research Plan (MRF Formulation)

commonly used Smoothnesscost functions.





Truncated linear model $f(n) = \lambda \times \min(|n|, K)$



Truncated quadratic model. $f(n) = \lambda \times \min(n^2, K)$

Research Plan (MRF Formulation)

- A binary function with a single tunable variable. This value controls how much smoothing is applied.
- The linear and quadratic models have an extra parameter K. K is a truncation value that caps the maximum penalty.
- Choosing a suitable DataCost and Smoothness function as well as the parameter is important criteria for stereo technique

Research Plan (Application of BP)

- BP algorithm is one of the algorithm used to find an approximate solution for an MRF.
- BP is message passing algorithm , A node passes a message to an adjacent node only when it is received all incoming messages, excluding the message from the destination node itself.

Research Plan (Application of BP)

Below diagram shows message passed from x_1 tox_2

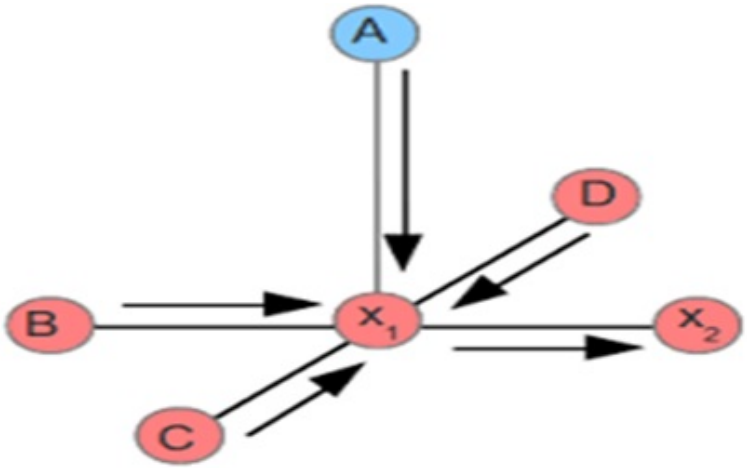


Figure: Message Passage in BP

Research Plan (Application of BP)

- To implement Belief Propagation two decisions should be made

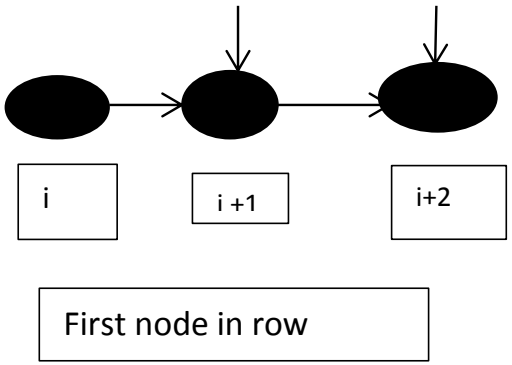
1. First one is max-product algorithm is used which finds the MAP estimate of the whole MRF
2. The second choice is Message Update Schedule

Research Plan (Application of BP)

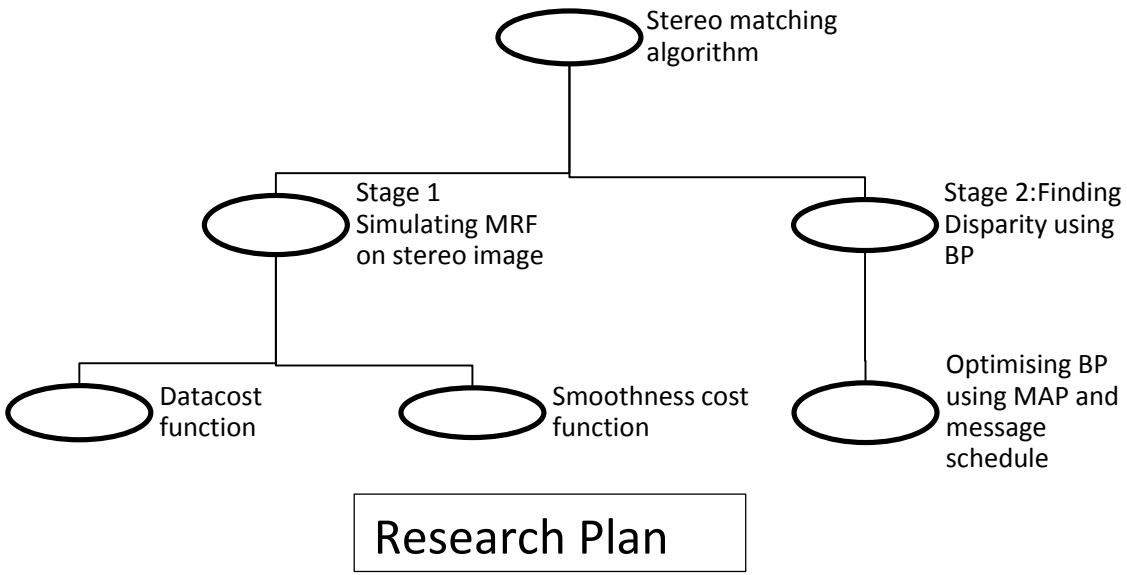
- An message schedule is to propagate messages in one direction and update each node immediately.
- For instance first node is in a row ,i would send message to the node at its right,i+1.Node i+1 would then use this message immediately along with the previously received from above and below to compute the message to the node i+2.
- Once this has been completed for every row,the same procedure occurs in the up,down and left directions. This schedule would only require one iterations for this information to propagated.
- This feature of the "$up - down - right - left$" message passing schedule causes the belief propagation algorithm to converge very quickly.

Research Plan (Application of BP)

Below diagram shows Message Update Schedule in BP



Research Plan



The problem statement and Expected Results

- By using different message passing schemes in belief propagation for stereo matching can reduce computational time of algorithm.The execution time of belief propagation reduces after certain stability or convergence criteria met,but termination of algorithm is depend on application of data.
- Development of a new or modify Belief Propagation optimization method by using different message passing scheme for stereo matching applications or cases of 3D objects.
  And Comparative analysis of new method with existing method.
- MATLAB is used to simulate functions in the proposed research work.

Conclusion

- The literature survey on major contributions in optimization of stereo matching technique using Belief Propagations are studied.
- The operational concepts and terms related to Markov Random Field and Belief propagation are studied.
- The implementation of stereo matching using BP are studied and understands the issues in implementation.

bibliography

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Thank You...